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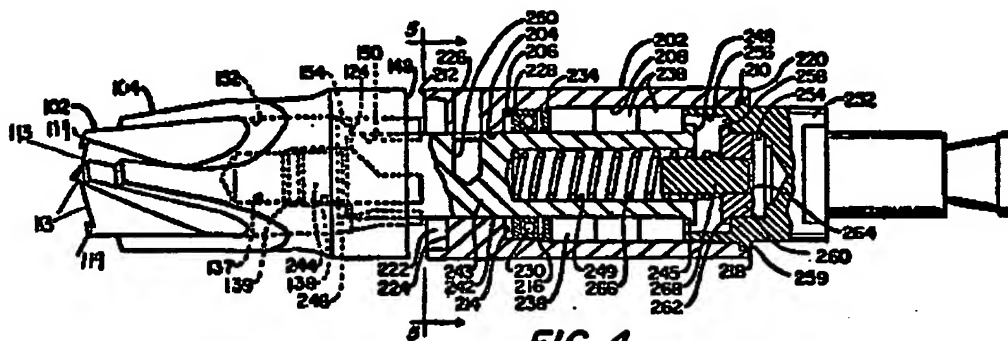
(58) Field of search

B3C

Selected US specifications from IPC sub-classes B23B
A61B

(54) Surgical drilling implement

(57) A drill-type cranial perforator comprises a front drill head assembly made up of a leading inner drill (102) and a trailing outer drill (104) and a rear support and drive assembly adapted to drive both drills so long as the leading inner drill is encountering a resistive surface and to disable both drills when the leading inner drill stops encountering the resistive surface. The inner drill (102) has at least one, e.g. three, flute(s) with a forward cutting edge, the edge including a reentrant segment (113) spaced from its outer end 119. The drill centre has a forward pyramid shape. Cutting edges of the outer drill (104) are aligned with extending blades of the inner drill.



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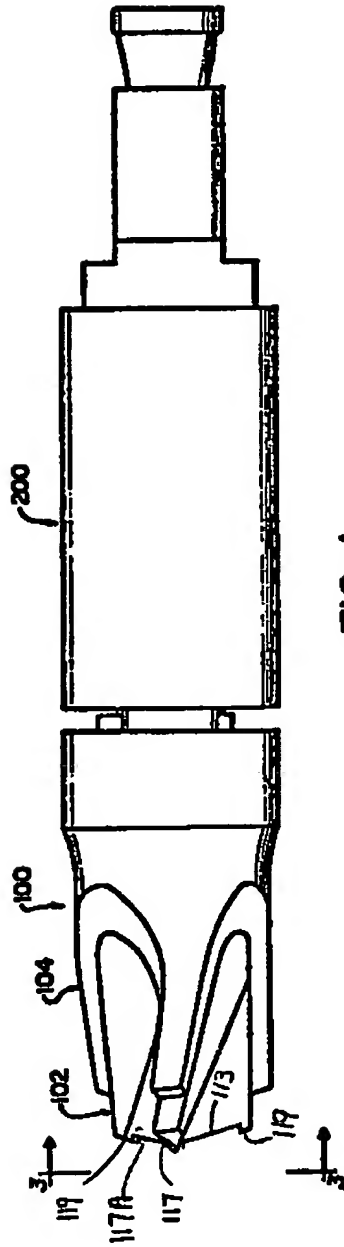


FIG. 1

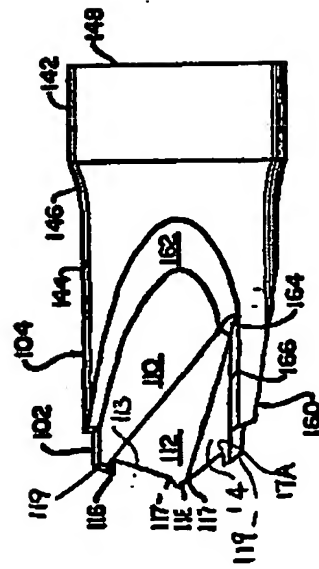


FIG. 2

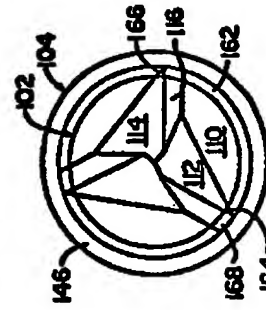


FIG. 3

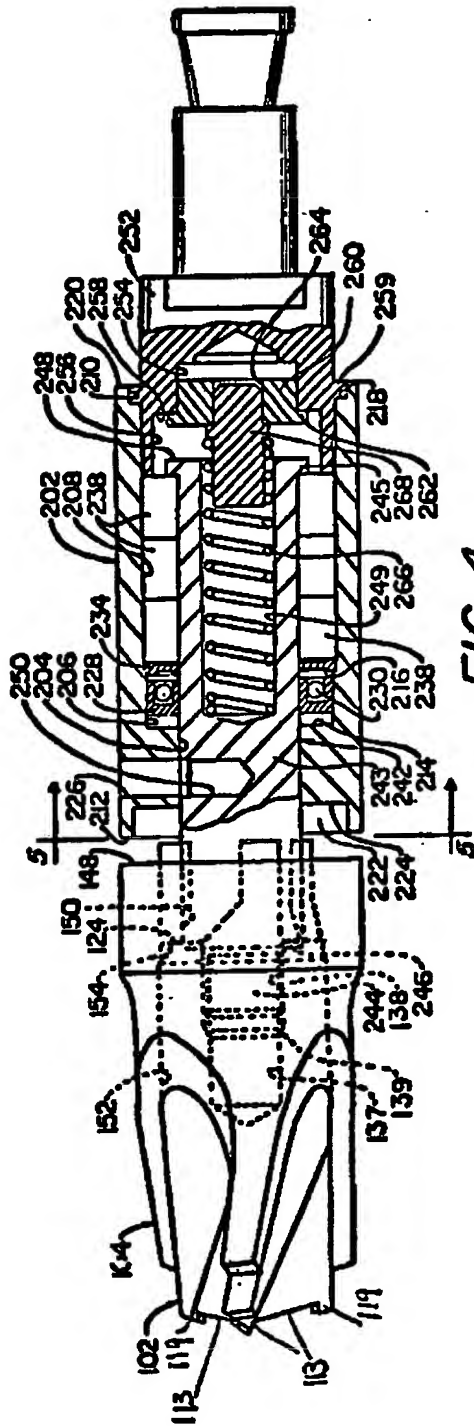


FIG. 4

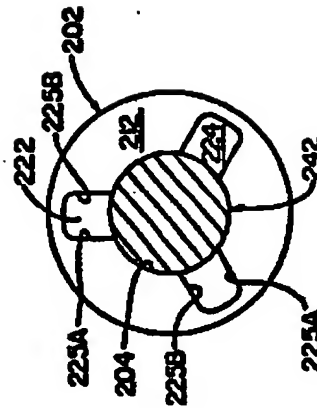
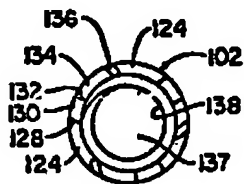
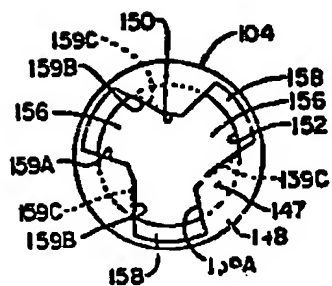
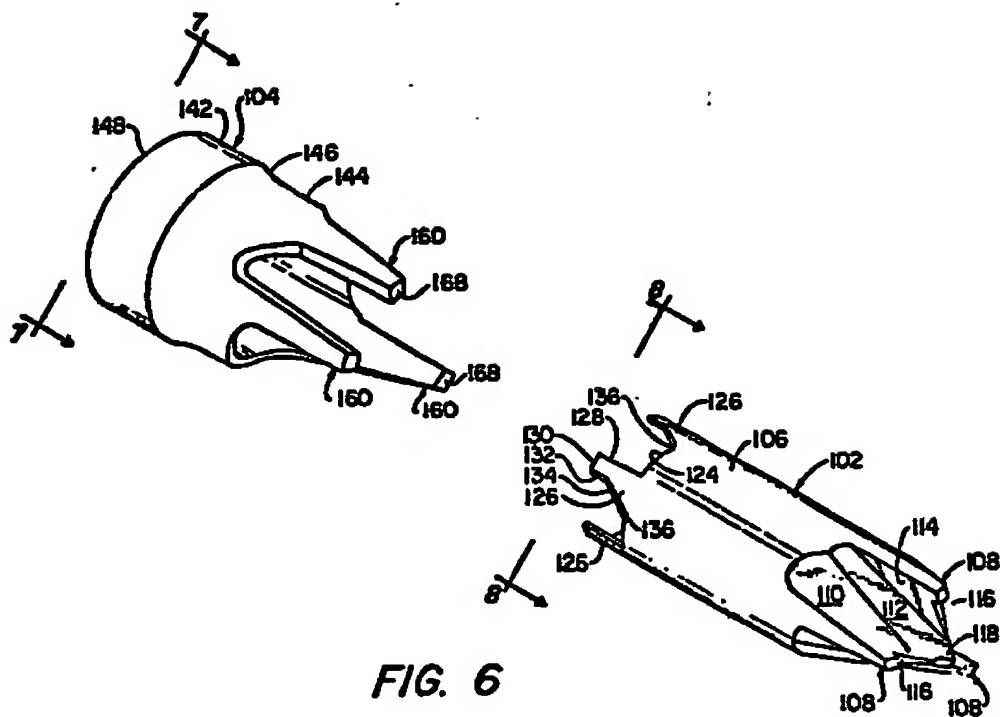


FIG. 5



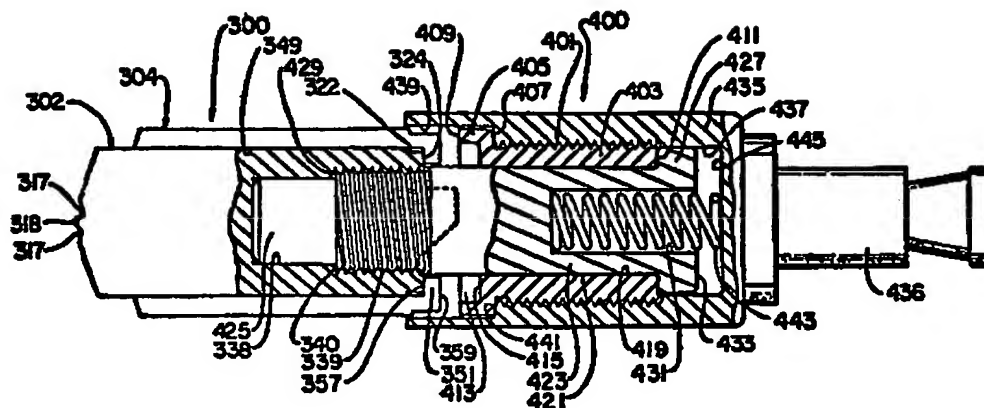


FIG. 9

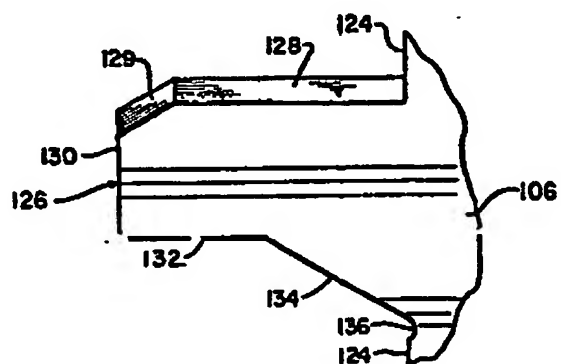


FIG. 13

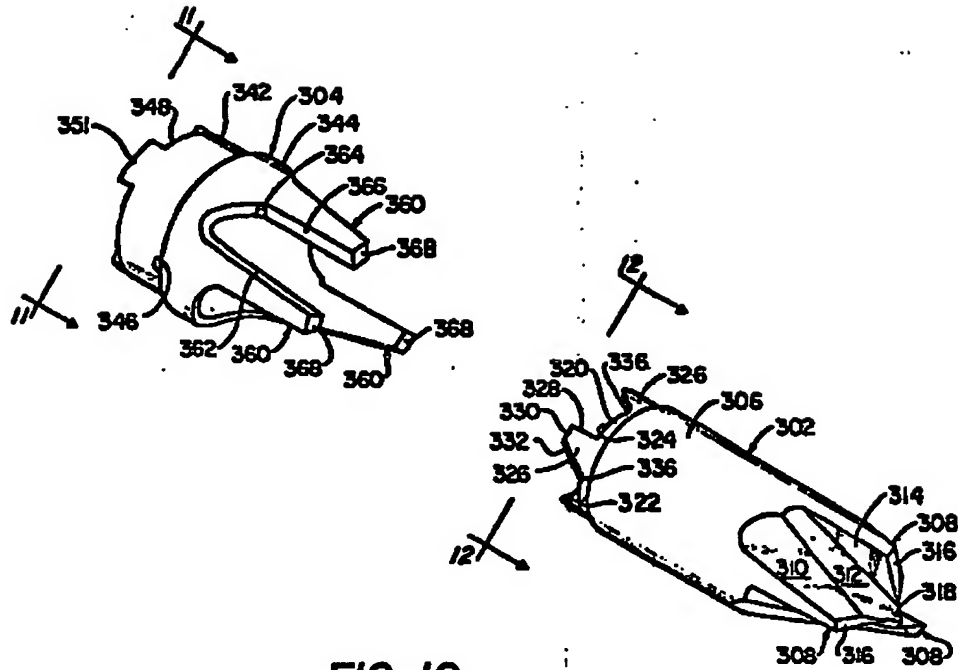


FIG. 10

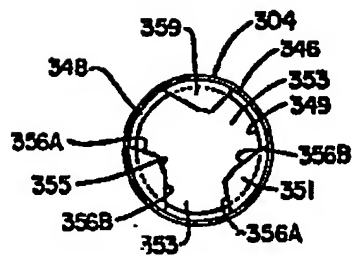


FIG. 11

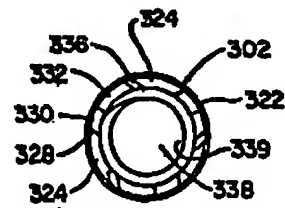


FIG. 12

SPECIFICATION

Surgical drilling implement

5 This invention relates to drilling implements for use as surgical instruments, and more particularly to cranial perforators and also to a method of drilling through bone structure.

10 Cranial perforators are special purpose drills which are used to bore holes through the skull during cranial surgery. Such holes may be needed to vent fluids from the region surrounding the brain, to provide small passageways to the brain for the insertion and removal of instruments, or to position a cranial saw for subsequent use in removing a larger piece of the skull.

15 Regardless of the end use of the hole being made, it is critical that the cranial perforator stop its boring action before it encounters—and thereby damages—the delicate dura tissue surrounding the brain, or the brain itself. To this end, cranial perforators have traditionally utilized a special "safety construction" designed to permit forward penetration by the perforator only so long as the perforator's leading tip is encountering hard bone, and to halt forward penetration by the perforator as soon as the perforator's leading tip passes through the hard bone and before it encounters the soft tissue beneath the bone. More particularly, cranial perforators have traditionally comprised a drill head assembly having a pair of drills disposed in concentric relation to one another, with the inner drill leading the outer drill slightly so that a bore-counterbore opening is formed as the perforator penetrates into the skull. The two drills are coupled to a rear support and drive assembly via a special clutch arrangement such that both drills are enabled so long as the leading inner drill is encountering a resistive surface (i.e., bone) and both drills are disabled as soon as the inner drill stops encountering the resistive surface (i.e., as soon as it passes through the bone). Inasmuch as the leading inner drill and trailing outer drill are adapted to cut in a bore-counterbore arrangement, the shoulder of bone formed at the intersection of the bore-counterbore opening impedes further progress of the perforator toward the brain once the leading inner drill is disabled. As a result, the surgeon using the cranial perforator can concentrate entirely on the placement of the cranial hole and need not fear that the perforator will penetrate too far into the head so as to damage the delicate dura tissue or the brain itself.

20 Cranial perforators using the aforementioned "safety construction" are known in both reusable and disposable form.

25 Unfortunately, the cranial perforators developed prior to this invention are believed to suffer from one or more serious deficiencies. For example, some of the prior art cranial per-

forators are believed to be unreliable with regard to the operation of their special "safety construction". Such unreliability is intolerable since a failure of the "safety construction" to operate as intended can have catastrophic effects. At least some prior drill-type cranial perforators of the type described above have been prone to failure or to unreliable operation of their "safety construction" under non-axial loading. Because the prior safety construction usually involves a pair of diametrically-opposed member coupling the drill head assembly to the rear support and drive assembly, non-axial loading of the drill head assembly can give rise to a chattering action of sufficient magnitude to prematurely terminate the useful life of the safety construction of the perforator or to cause the safety construction to operate unreliably, e.g. possibly by intermittently disengaging the drill head assembly from the rear support and drive assembly. Other problems with prior art devices involve difficulty of manufacturing component parts with necessary precision, so that both quality and cost tend to suffer. Furthermore, it appears that virtually all or many prior art cranial perforators have proven difficult to center when starting a bore. This is particularly true when the bore site is well lubricated by blood or other fluids, so that the perforator has a tendency to skate or slip along the outside of the skull. This can result in unnecessary added injury to the patient. Also, at least some prior art cranial perforators tend to render unusable the cranial material removed from the bore site, with the result that the holes made by such perforators may have to be refilled with foreign material at the close of surgery rather than with the patient's own bone matter. Also, most, if not all, prior art cranial perforators have required relatively high speed drilling (i.e., drilling at speeds of around 800-1000 RPM), which tends to be less desirable than low-speed drilling (i.e., drilling at speeds of around 100 RPM) for a variety of reasons.

30 In addition to the foregoing, in some prior art reusable cranial perforators, the rear support and drive assembly and/or the clutch means are inadequately designed to withstand repetitive non-axial loading, with the result that they fail after an indefinite period of use. Also, many prior art reusable cranial perforators are designed so that they must be disassembled into numerous pieces to effect proper cleaning, with the result that disassembly and subsequent reassembly tend to be fairly complicated and time-consuming. Moreover, with many prior art designs, if reassembly is improperly effected, the perforator's special "safety construction" may be rendered totally inoperative, in which case the perforator's forward penetration will not be halted automatically as soon as its leading tip passes through the skull, and damage to delicate tissues can ensue unless the surgeon is skillful and obser-

vant enough to prevent penetration into the dura.

In addition to the foregoing, disposable cranial perforators heretofore known have generally lacked safeguards to ensure that the perforator cannot be reused.

Cranial perforators making use of inner and outer drills have, on occasion, lacerated or damaged the dura when the inner drill snaps forward as it cuts through the inner surface of the skull. This is particularly true in older people since the dura is ordinarily closer to the skull. In addition, the inner drill may engage a bone fragment or "petal" as it cuts through the inner surface of the skull and drive it through the dura into the brain, causing serious injury. Such "petals" are particularly dangerous inasmuch as they are small and may have sharp cutting edges. Even though the inner drill may have disengaged on penetration of the skull, the inertia of the drill, turning at speeds of up to 1000 RPM, can impart considerable force to these petals.

Accordingly, one of the objects of the present invention is to provide a novel and improved drill-type cranial perforator having a reliable "safety construction" designed to permit forward penetration by the perforator only so long as the perforator's leading tip is encountering hard bone, and to halt forward penetration by the perforator as soon as the perforator's leading tip passes through the hard bone and before it encounters the soft tissue beneath the bone.

According to one aspect of the invention there is provided a drilling implement for drilling holes in bone structures comprising, a drill head assembly including inner and outer coaxial drill members with the inner member having at least one drilling flute with a forward cutting edge, said cutting edge including a reentrant segment spaced from the outer end of said forward cutting edge and extending inwardly to the axis of said drill members.

Preferably, the drilling implement has a plurality of said flutes, said cutting edges extending outwardly from a common center point which project forwardly of said forward cutting edges. Conveniently, there are three flutes which form a pyramid with said common center point.

In a preferred embodiment, the outer ends of the forward cutting edges form shoulders which project forwardly to a point short of the forward most position of said center point. Desirably, the outer end of said forward cutting edge projects forwardly of said reentrant segment a distance in the order of magnitude of at least 0.005 inches and said reentrant segment extends inwardly a major fraction of the diameter of said inner drill.

According to another aspect of the invention, there is provided a method of drilling through bone structure comprising drilling a cylindrical hole through the bone structure with

an annular channel being simultaneously cut with and at the bottom of the hole, whereby a cylindrical wafer or pillow is formed at the bottom of the hole when the bone structure is initially cut through along said annular channel and discontinuing drilling immediately upon formation of said wafer or pillow.

The preferred cranial perforator has improved means for coupling the front drill head assembly to the rear support and drive assembly, so as to effectively assure automatic de-clutching of the drill head assembly from the support and drive assembly as the tip of the perforator penetrates the far side of the bone, even when the perforator is manipulated under non-axial loads. It is also relatively easy to manufacture with high precision tolerances and includes novel centering means to assist in centering the perforator when starting a bore, so as to minimize the tendency of the perforator to skate over the outer surface of the skull. Furthermore, it is adapted to remove bone material from a cranial opening in a form best suited for subsequent repacking in the opening when the opening is closed at the conclusion of surgery and can be used with relatively slow speed drills (i.e. drills operating at speeds of around 100 RPM), as well as with relatively high speed drills (i.e., drills operating at speeds of around 800-1000 RPM).

An advantage of the invention is that it provides a reusable cranial perforator better adapted to withstand repetitive non-axial loading, so that the perforator will not tend to fail after an indefinite period of use. It also has a long operational lifetime, is easy to disassemble and to reassemble so as to facilitate cleaning, and which disassembles into relatively few pieces so as to facilitate disassembly and reassembly. A further advantage of the preferred reusable cranial perforator is that it can be rendered totally inoperative if it should be reassembled incorrectly and it cannot be disassembled without rendering the perforator totally inoperative.

Preferably, the disposable cranial perforator will indicate when it has been resterilized in an attempt to use it more than once.

The drilling implement of the invention can be used to bore holes in various kinds of bone matter, e.g. cranial bone, breast bone, etc., and its inner and outer drill members minimize or eliminate dangers of lacerating or otherwise damaging the dura as the inner drill cuts through the inner surface of the skull. The preferred drill includes means which minimizes or eliminates the likelihood that bone fragments or "petals" will be driven by the rotating drill into the brain. It also includes improved means for isolating the cutting edge from the dura and brain by creating a "wafer" like segment of bone as the inner drill cuts through the skull. This wafer like segment which may be termed a "pillow" is formed between the dura and major portion of the

cutting edge of the inner drill. When the inner drill is disengaged, the pillow also functions as a means for separating the dura from the skull.

- 5 The preferred drill-type cranial perforator to be described hereafter comprises a front drill head assembly made up of a leading inner drill and a trailing outer drill, and a rear support and drive assembly adapted to enable both
- 10 drills so long as the leading inner drill is encountering a surface offering a predetermined loading and to disable both drills when the leading inner drill stops encountering the predetermined loading. The novel perforator is
- 15 characterized by one or more of the following features: (1) a unique clutch arrangement coupling the front drill head assembly to the rear support and drive assembly and arranged so as to avoid decoupling and minimize stresses imposed by non-axially directed loading; (2) a
- 20 novel centering means on the leading drill member to prevent "skating"; (3) a unique support and drive assembly designed to retard failure caused by repetitive non-axial loading; (4) a unique support and drive assembly that prevents disassembly and reuse of the perforators; (5) means integral with the leading drill member for cutting a "pillow" like element from the skull, which element isolates the cutting edge of the leading drill from the dura and brain; and (6) means for minimizing the likelihood of creating bone fragments or petals which can be driven by the inner drill through the brain.

- 35 A preferred embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:-

40 *Figure 1* is a side elevation of a reusable cranial perforator which comprises the preferred embodiment of the present invention;

45 *Figure 2* is a side elevation of the drill head assembly of the same reusable cranial perforator rotated 60 degrees from the position shown in *Fig. 1*;

Figure 3 is a front elevation of the same reusable cranial perforator, taken from the viewpoint represented by line 3-3 in *Fig. 1*;

50 *Figure 4* is a side elevation, partially in section, of the same reusable cranial perforator, with the perforator's support and drive assembly rotated 90 degrees from the position shown in *Fig. 1*;

55 *Figure 5* is a cross-section of the same reusable cranial perforator, taken along line 5-5 of *Fig. 4*;

Figure 6 is an exploded perspective view of the drill head assembly of the same reusable cranial perforator;

60 *Figure 7* is a rear elevation of the outer drill of the same reusable cranial perforator, taken from the viewpoint represented by line 7-7 in *Fig. 6*;

65 *Figure 8* is a rear elevation of the inner drill of the same reusable cranial perforator, taken

from the viewpoint represented by outline 8-8 in *Fig. 6*;

70 *Figure 9* is a side elevation, partially in section, of a disposable cranial perforator which comprises an alternative embodiment of the present invention;

Figure 10 is an exploded perspective view of the drill head assembly of the same disposable cranial perforator;

75 *Figure 11* is a rear elevation of the outer drill of the same disposable cranial perforator, taken from the viewpoint represented by line 11-11 in *Fig. 10*;

80 *Figure 12* is a rear elevation of the inner drill of the same disposable cranial perforator, taken from the viewpoint represented by line 12-12 in *Fig. 10*;

85 *Figure 13* is an enlarged fragmentary showing an alternative embodiment of the inner drill's lugs; and

90 *Figure 14* is a schematic enlarged fragmentary elevational view of the cutting end of the embodiment of *Fig. 1* as it cuts through the skull, with portions of the skull dura and brain in schematic.

Detailed description of the preferred embodiment

Looking first at *Fig. 1*, there is shown a reusable cranial perforator constituting a preferred embodiment of the present invention. As seen in *Fig. 1*, the reusable cranial perforator generally comprises a front drill head assembly 100 and a rear support and drive assembly 200. Front drill head assembly 100 comprises an inner drill or drill member 102 and an outer drill or drill member 104.

Inner drill 102 is shown in *Figs. 1-4, 6* and 8. Drill 102 is generally cylindrical in nature and comprises a cylindrical midsection 106 (*Fig. 6*). The front end of drill 102 is dissected by a plurality of inclined intersecting surfaces so as to define three prismatic flutes or blades identified generally at 108. More particularly, the three flutes 108 comprise a trio of first inclined surfaces 110, a trio of second inclined surfaces 112, and a trio of third inclined surfaces 114, plus a trio of end surfaces 116, with each of the latter being intersected by surfaces 110 and 112 of one flute and surface 114 of another flute. Flutes 108 are disposed 120 degrees apart from one another.

Accordingly, each of the surfaces 110, 112 and 114 of each flute is displaced 120 degrees from the corresponding surface of the other two flutes. On account of the relative dispositions of the inclined surfaces 110, 112, and 114, each of the flutes 108 terminates in a pyramidal end projection 118 which extends outward beyond the front end surfaces 116 of flutes 108 (*Figs. 2* and 6). The planes of surfaces 114 are eccentric to the lead point of pyramidal end projection 118, and end surfaces 116 are pitched at a 6 1/2 degree

angle in the circumferential (i.e., non-radial) direction. The leading edges of surfaces 116 constitute front cutting edges. The outer edges of surfaces 114 also constitute cutting edges. The front cutting edges 116 are each formed with a reentrant segment 113 that extends from the base of projection 118 at 117, outwardly toward the outer ends of said cutting edge, terminating short of the outer end at 117A, thereby defining shoulders 119. The shoulder 119 projects forwardly to a point short of the forward most positions of the center point 118.

In a preferred embodiment of the invention the outer diameter of the outer drill member may be .562", the outer diameter of the inner drill member may be .437", the width of the shoulder at the outer end of the cutting edge may be .050", thereby defining the diameter of the wafers or pillows which are formed as 0.337" (.437"-.10). The distance between parallel planes passing respectively through the forwardmost end of the common center point and the outer most end of the edges 116 on the shoulders 119 may be .050", while the depth of the reentrant segment 113 may be .035". These dimensions may vary and therefore, should be considered exemplary of a drilling implement of preferred dimensions.

The rear end of cylindrical midsection 106 terminates in an end surface or wall 124 (Fig. 4, 6 and 8). A trio of lugs or keys or fingers 126 extend rearward from end surface 124. Rearwardly projecting lugs 126 are formed integral with cylindrical midsection 106 and are disposed 120 degrees apart from one another. Each of the lugs 126 is shaped so that it has a first side surface 128 which extends parallel to the center axis of drill member 102 and perpendicular to end surface 124, an end surface 130 which extends substantially parallel to end surface 124, a second side surface 132 which extends substantially perpendicular to end surface 124 (and end surface 130), and a third side surface 134 which extends at an inclined angle (i.e., non-perpendicular) to end surface 124. A small groove 136 is formed at the intersection of each inclined side surface 134 and end surface 124.

Inner drill 102 also includes an axial bore 137 which begins at rear end surface or cylindrical midsection 106 and terminates in the middle of midsection 106, and a somewhat shallower threaded counterbore 138 which begins at rear end surface 124 of cylindrical midsection 106 and terminates at a shoulder 139 in the middle of midsection 106 (Figs. 4 and 8).

Outer drill 104 is shown in Figs. 1-4, 6 and 7. Outer drill 104 is generally cylindrical in nature, and is cut away in a selected manner so as to form a series of flutes or blades at its front end. More particularly, outer drill 104 comprises a substantially cylindrical rear section 142 which is joined to a generally cylin-

dricl front section 144 by a substantially frustoconical section 146 (Figs. 2, 3 and 6). Rear section 142 terminates in a rear surface 148 (Figs. 2, 4, 6 and 7). Outer drill 104 includes an axial bore 152 (Figs. 4 and 7), and three inwardly extending lips 147 having forward surfaces 154 (Fig. 4) and curved inside surfaces 150 which are arcs of a circle concentric to the axis of the outer drill. Outer drill 104 also includes a trio of slots 156 extending between lips 147. Slots 156 are spaced 120 degrees apart from one another. Each of the slots 156 forms a shoulder 158. Each of the lips 147 has side wall surfaces 159A and 159B. Lips 147 are beveled away at their forward sides so that surfaces 159C extend between side wall surfaces 159B and forward surfaces 154. Surfaces 159C are planar in nature and extend at a 45 degree angle to side wall surfaces 159B and at a 45 degree angle to forward surfaces 154, for reasons which will hereinafter be made clear.

Referring next to Figs. 1, 2, 3, 4, and 6, the outer drill's generally cylindrical front section 144 is dissected by a plurality of inclined intersecting surfaces so as to define three flutes or blades identified generally at 160. More particularly, the three flutes comprise a trio of first inclined surfaces 162, a trio of second inclined surfaces 164, and a trio of third inclined surfaces 166 (Figs. 2 and 3). Flutes 160 are disposed 120 degrees apart from one another, and each terminates in a front end surface 168 (Figs. 3 and 6). Front end surfaces 168 are pitched at a 3 degree angle in the circumferential (i.e., non-radial) direction. The leading edges of surfaces 168 are front cutting edges, while the outer edges of surfaces 166 constitute side cutting edges.

Inner drill 102 and outer drill 104 are assembled concentrically one inside the other so as to form the complete drill head assembly 100. More particularly, inner drill 102 and outer drill 104 are positioned in the manner shown in Fig. 6, i.e., so that the inner drill's flutes 108 are aligned with the outer drill's flutes 160, and so that the inner drill's lugs 126 are aligned with the outer drill's slots 156. Then the two drill members are brought together, so that the inner drill slips inside and makes a close sliding fit with the outer drill, with the inner drill's end wall 124 coming to rest against the forward surfaces 154 of lips 147 (Fig. 4). The various parts of the inner and outer drills are sized and shaped so that when the drill head assembly is put together with the inner drill's end surface 124 engaging the outer drill's surfaces 154, and the lugs 126 are located in slots 156, the outer drill's front end cutting surfaces 168 will be aligned with and behind the inner drill's front end surfaces 116, the outer drill's first inclined surfaces 162 will form a rearward extension of the inner drill's first inclined surfaces 110, the outer drill's second inclined surfaces 164 will

form a rearward extension of the inner drill's second inclined surfaces 112, and the outer drill's third inclined surfaces 166 will form a rearward extension of the inner drill's third inclined surfaces 114 (Figs. 2, 3 and 4). In addition, the inner drill's lugs 126 are sized so that when the inner drill's end wall 124 engages the outer drill's surfaces 154, the lugs 126 extend out through the outer drill's slots 156, with the lugs' first side surfaces 128 residing adjacent and parallel to side surfaces 159A of lips 147, and the lugs' inclined side surfaces 134 residing adjacent and parallel to bevelled surfaces 159C of lips 147. In addition, the inner drill's lugs 126 are sized so that they extend out beyond the outer drill's rear surface 148 when the inner drill's end wall 124 engages surfaces 154 of outer drill 104 (Figs. 1 and 4).

It is to be appreciated that the foregoing assembly can be achieved only if inner drill 102 and outer drill 104 are properly aligned with one another (i.e., so that the inner drill's flutes 108 are aligned with the outer drill's flutes 160, and so that the inner drill's keys 126 are aligned with the outer drill's slots 156) prior to moving the two drills into engagement. On account of the size and shape of the inner drill's lugs 126 and the size and shape of outer drill 104, if the lugs 126 are not properly aligned with the outer drill's slots 156 when the two drill members are moved together, the end surfaces 130 of the inner drill's keys 126 will encounter the forward surfaces 154 of lips 147 and thereby prevent the inner and outer drills from achieving the position shown in Fig. 4.

Rear support and drive assembly 200 is shown in Figs. 1, 4 and 5. Assembly 200 comprises a cylindrical outer sleeve 202. Sleeve 202 includes an axial bore 204, a first axial counterbore 206, a second axial counterbore 208, and a third axial counterbore 210. Axial bore 204 begins at the sleeve's front end surface 212 and extends rearward to counterbore 206. A shoulder 214 is formed at the intersection of bore 204 and counterbore 206. Counterbore 206 in turn extends rearward to counterbore 208. A shoulder 216 is formed at the intersection of counterbore 206 and counterbore 208. Counterbore 208 extends rearward to counterbore 210. A shoulder 218 is formed at the intersection of counterbore 208 and counterbore 210. Counterbore 210 intersects the sleeve's rear end surface 220. Sleeve 202 also includes a trio of key-receiving recesses 222 formed in the sleeve's front end surface 212 (Figs. 4 and 5). Recesses 222 are spaced 120 degrees apart from one another and have bottom surfaces 224. Each of the recesses 222 is defined by side wall surfaces 225A and 225B. A radial bore 226 extends through the side wall of sleeve 202.

An annular seal 228 (Fig. 4) is disposed

within counterbore 206 concentric with the axis of sleeve 202. Seal 228 has a C-shaped cross-section and is formed out of a resilient material, e.g. a soft rubber. An expander element, e.g. a resilient O-ring 230, is positioned inside the seal to keep it radially extended for the purpose hereinafter described.

An annular spacer element 234 is disposed within counterbore 208. Spacer element 234 rests against shoulder 216 and is sized so that its inner surface lies flush with the inner surface of sleeve 202.

Also disposed within counterbore 208 are three annular bearing members 238. Bearing members 238 are sized so that their innermost surfaces are flush with the surface of sleeve 202 which defines bore 204, and also with the innermost surface of spacer element 234.

A coupling or connecting pin 242 is slidably disposed within sleeve 202 and annular members 228, 234 and 238. Pin 242 is formed with a cylindrical midsection 243, a threaded cylindrical reduced diameter front section 244, and a rear flange 245 having an enlarged diameter relative to cylindrical midsection 243. A shoulder 246 is formed at the intersection of threaded cylindrical front section 244 and cylindrical midsection 243, and rear flange 245 terminates in an end surface 248. Connecting pin 242 is sized so that its cylindrical midsection 243 makes a close sliding fit in bore 204 of sleeve 202, and also with the innermost surfaces of seal 228 and spacer element 234 and bearings 238. As a result, connecting pin 242 is free to move independently of sleeve 202. At the same time, on account of the fact that the inside wall of seal 228 is urged by expander element 230 to assume a position slightly further inward than the surface of sleeve 202 which defines bore 204, resilient seal 228 engages and makes a good seal with the outer surface of the connecting pin's cylindrical midsection 243. This engagement is sufficient to prevent liquid or solid substances from passing between seal 228 and the connecting pin, but it is not sufficient to significantly inhibit the movement of connecting pin 242 relative to sleeve 202.

Connecting pin 242 also includes an axial bore 249 which begins at its rear surface 248 and extends into the pin's cylindrical midsection, and a radial bore 250 which begins at the pin's outside surface and extends into midsection 243. Radial bore 250 is positioned so that it will be aligned with the sleeve's bore 226 when the connecting pin's rear flange 245 is in engagement with the rearmost bearing 238, and radial bore 250 has a diameter identical to the diameter of radial bore 226.

Means are provided to urge connecting pin 242 forward so that the pin's rear flange 245 normally engages the rearmost bearing 238, in the manner shown in Fig. 4. More particularly, the rear support and drive unit 200 includes a

drive adapter 252 which closes off the rear of sleeve 202. Adapter 252 has a stepped-down exterior configuration at its rear end which is adapted to be received by a Hudson chuck, as will hereinafter be described in further detail. Adapter 252 includes an axial bore 254, an axial counterbore 256, a shoulder 258 formed at the intersection of bore 254 and counterbore 256, and a peripheral flange 259. Adapter 252 is press fitted into the sleeve's counterbore 208, with its peripheral flange 259 making a close fit in the sleeve's counterbore 210. The inner end of the adapter 252 engages the rearmost bearing 238 and thereby captivates the bearings in sleeve 202. A thrust bearing unit 260 having a circular peripheral flange 262 is disposed in the end cap's bore 254 and counterbore 256, in the manner shown in Fig. 4. Bearing unit 260 includes an axial through-hole 264 which accommodates a mandrel or spring pin 268 which serves as an anchor for a compression spring 266. The latter extends into bore 249 of pin 242. This construction suffices to keep the connecting pin's rear flange 245 biased against the rearmost bearing member 238, without significantly impeding the rotation of connecting pin 242 relative to sleeve 202. At the same time, pin 242 is capable of axial motion relative to sleeve 202 to the extent permitted by the gap normally residing between the pin's flange 245 and thrust bearing 260.

It will be appreciated that rear support and drive assembly 200 essentially forms a self-contained unit wherein connecting pin 242 projects its threaded front end 244 outward from the front end of sleeve 202 and is yieldably biased into that position, and further wherein the connecting pin is capable of rotation relative to sleeve 202.

The front drill head assembly 100 is united with the rear support and drive assembly 200 by screwing the connecting pin's threaded cylindrical front section 244 into the inner drill's threaded counterbore 138, so that the connecting pin's shoulder 248 engages the inner drill's end surface 124.

The various parts of the cranial perforator are sized so that the drill head assembly can only be screwed onto connecting pin 242 when the inner drill's lugs 126 extend through the outer drill's slots 156, for reasons which will hereinafter be described in detail. In addition, the various parts of the cranial perforator are sized so that when the drill head assembly and the support and drive assembly are so united, and the connecting pin's rear flange 245 is in engagement with the rearmost bearing unit 238, the inner drill's lugs 126 will terminate short of the sleeve's front end surface 212 (Fig. 4). At such time, the lugs are incapable of being locked to sleeve 202 so that sleeve 202 cannot drive the drill head assembly. At the same time, however, the

various parts of the cranial perforator are sized so that when the front drill head assembly and the rear support and drive assembly are united in the foregoing manner, and the inner drill 102 is thereafter forced rearwardly relative to sleeve 202 against the action of spring 266, the lugs 126 can extend into the key-receiving recesses 222 before the connecting pin's rear surface 248 contacts bearing unit 260, whereby the lugs can lock the drill head assembly to the sleeve so as to cause the two to rotate together.

Operation of the cranial perforator will now be described.

The assembled cranial perforator is prepared for use by fitting the perforator's adaptor 252 into a Hudson chuck which is disposed on the end of the drive shaft of a suitable driver. Subsequent rotation of the drive shaft in a counterclockwise direction (as viewed in Fig. 3) will cause the rear support and drive unit 200 to rotate in the same counterclockwise direction. On account of some residual friction between connecting pin 242 and the remainder of the rear support and drive unit 200, the front drill head assembly 100 will generally tend to rotate with rear support and drive unit 200 so long as the front drill head assembly is not encumbered by any braking action. However, if any braking action whatsoever is applied to inner drill 102 while the rear support and drive unit 200 is rotating, without the inner drill being subjected to a rearward force sufficient to overcome the force of spring 266, the perforator's aforementioned construction will allow front drill head assembly 100 to stop rotating even while rear support and drive unit 200 continues to rotate. Similarly, if any braking action is applied to outer drill 104 while the rear support and drive unit 200 is rotating and while the inner drill is not subjected to a rearward force sufficient to overcome the force of spring 266, the non-rotating outer drill will be cammed backward by virtue of the engagement of the inclined surfaces 134 of lugs 126 with surfaces 159C of lips 147, until the outer drill's rear end surface 148 contacts the sleeve's front end surface 212, and while so positioned the outer drill will be in sliding engagement with the rotating sleeve. As soon as the outer drill's surfaces 159B contact side surfaces 132 of the inner drill's lugs 126, rotation of the inner drill will also cease, the continued rotation of the rear support and drive unit 200 notwithstanding.

Now when the cranial perforator is to be used to drill a hole in a skull, the powered drive unit (not shown) drives the cranial perforator in a counterclockwise direction. The cranial perforator is brought down so that its pyramidal front projection 118 contacts the skull precisely where the cranial hole is to be made. As the sharp pyramidal projection 118 keeps the cranial perforator centered, the per-

forator is pressed down against the skull so that inner drill 102 and connecting pin 242 are forced backwards against the pressure of spring 166. This action allows the inner drill's lugs 126 to enter recesses 222 of the rotating sleeve 202, so that the surfaces 128 of lugs 126 are engaged by the sleeve's surfaces 225B, with the result that rotation of the sleeve is imparted to the inner drill. As the inner drill rotates, its pyramidal projection 118 and its flutes 108 bore into the skull. At the same time, the outer drill's surfaces 159C are engaged by the rotating lugs' surfaces 134, causing the outer drill to rotate in unison with the inner drill. As the perforator cuts its way into the skull, the leading inner drill's flutes 108 cut a bore, and the trailing outer drill's flutes 260 cut a counterbore, so that a bore-counterbore opening is formed in the skull. Because front end surfaces 168 are cut at a flatter angle than front end surfaces 116, the outer drill will tend to encounter greater cutting resistance than the inner drill.

When the leading tip of the inner drill passes through the target bone, so that it no longer meets a resistive surface and is free to slip forward, the camming action of the outer drill's bevelled surfaces 159C bearing against the inner drill's lug surfaces 134 causes the inner drill to slip forward relative to the outer drill and the rear support and drive assembly far enough for lugs 126 to move out of recesses 222 and thereby disengage themselves from sleeve 202. With the inner drill no longer coupled to the rear support and drive unit 200, residual friction with the skull causes the rotation of drills 102 and 104 to cease. Further forward penetration of the cranial perforator is impeded at this point, inasmuch as the bore-counterbore made by the cranial perforator has formed a solid shoulder of bone which blocks the front surfaces 168 of the now-stationary outer drill. The cranial perforator may be removed from the cranial opening simply by pulling it backward.

On account of the number and shape of the inner drill's lugs 126 and the number and shape of the sleeve's lug-receiving recesses 222, and also on account of the manner in which connecting pin 242 is maintained within sleeve 202, the coupling between the front drill head assembly 100 and the rear support and drive assembly 200 provides reliable service during drilling even when the perforator is subjected to a variety of non-axial loadings. Three lugs 126 are provided so as to prevent wobbling of the inner drill, maintain positive locking of the inner drill to the sleeve 202 at all times when the perforator is pressed tightly against bone, and assure that de-clutching of the drill head assembly will occur automatically whenever the inner drill encounters a drop in resistance from the surface which it is drilling. Using two or four lugs for coupling the inner drill to the sleeve is undesirable since then

there is a tendency for the inner drill to wobble, i.e., to shift laterally about a transverse pivot axis under non-axial loading. This wobbling action is detrimental since it creates a friction buildup between the inner and outer drills which may be great enough to prevent reliable de-clutching of the drill head assembly.

Because of the unique construction of the inner drill's flutes 108 and the outer drill's flutes 160, drilling can be conducted at relatively low speeds (i.e., at speeds of around 100 RPM), rather than at the relatively high speeds (i.e., speeds of around 800-1000 RPM) required of prior art devices in order for them to function properly.

Furthermore, the particular shapes of the inner drill's flutes 108 and the outer drill's flutes 160 enable removal of bone material from the cranial opening in a form best suited for subsequent repacking in the opening when the opening is closed at the conclusion of surgery.

The cranial perforator described and illustrated above is intended to be reused numerous times before being discarded. At the conclusion of the operation, the perforator may be easily disassembled for more complete cleaning. To accomplish disassembly, the front drill head assembly is rotated so that the attached connecting pin's radial bore 250 is aligned with the sleeve's radial bore 226. Then a tool is inserted into radial bores 226 and 250 so as to lock the connecting pin against rotation relative to sleeve 202. Thereafter, the front drill head assembly is unscrewed from the locked connecting pin, and the inner drill is separated from the outer drill. The three parts (i.e., the inner drill, the outer drill, and the rear support and drive assembly) may then be washed and sterilized. In this respect it is noted that the rear support and drive assembly generally requires no further disassembly for proper cleaning inasmuch as seal 228 prevents material from making its way into the rear portion of the support and drive assembly.

By carefully sizing the various parts of the cranial perforator so that front drill head assembly 100 cannot be screwed onto connecting pin 242 unless the inner drill's lugs 126 extend through the outer drill's slots 156, it is assured that the inner and outer drills can never be locked in position relative to one another so as to defeat the perforator's special "safety construction". Thus, reassembly of the cranial perforator after cleaning is rendered virtually foolproof.

Figs. 9-12 show a disposable cranial perforator which comprises an alternative embodiment of the present invention. This alternative embodiment comprises a front drill head assembly 300 and a rear support and drive assembly 400 (Fig. 9). Front drill head assembly 300 comprises an inner drill 302 and an outer drill 304.

Inner drill 302 is shown in Figs. 9, 10 and

12. Inner drill 302 is similar in shape to the inner drill 102 previously described. More particularly, the front end of inner drill 302 is identical to the front end of inner drill 102, inasmuch as the drill's cylindrical midsection 306 is dissected by a plurality of intersecting inclined surfaces so as to form three flutes 308 (Fig. 10). Specifically, the three flutes comprise a trio of first inclined surfaces 310, a trio of second inclined surfaces 312, and a trio of third inclined surfaces 314, plus a trio of end surfaces 316, with each of the latter being intersected by surfaces 310 and 312 of one flute and surface 314 of another flute. Flutes 308 are disposed 120 degrees apart from one another. Accordingly, each of the surfaces 310, 312 and 314 of each flute is displaced 120 degrees from the corresponding surface of the other two flutes. On account of the relative dispositions of inclined surfaces 310, 312, and 314, each of the flutes 308 has a front end notch 317, and the inner drill terminates in a pyramidal projection 318 which extends outward beyond the front end surfaces 316 of flutes 308 (Figs. 9 and 10). The planes of surfaces 314 are eccentric to the lead point of pyramidal end projection 318, and end surfaces 316 are pitched at a $6\frac{1}{2}$ degree angle in the circumferential (i.e., non-radial) direction.

Inner drill 302 also comprises a cylindrical rear section 320 which is formed integral with cylindrical midsection 306. Cylindrical rear section 320 has a slightly smaller diameter than cylindrical midsection 306, so that an exterior shoulder 322 is formed at the intersection of these two sections (Figs. 10 and 12). Cylindrical rear section 320 terminates in an end wall 324. A trio of lugs or keys 326 extend rearward from end wall 324. Lugs 326 are formed integral with cylindrical rear section 320 and are disposed 120 degrees apart from one another. Each of the lugs 326 is shaped so that it has a first side surface 328 which extends perpendicularly outward from end surface 324, an end surface 330 which extends substantially parallel to end surface 324, and a second side surface 332 which extends at an inclined angle (i.e., non-perpendicular) to end surface 324. A small groove 336 is formed in cylindrical rear section 320 at the intersection of each inclined side surface 332 and end surface 324.

Inner drill 302 also includes an axial bore 338 which begins at rear end surface 324 of cylindrical rear section 320 and extends into the middle of cylindrical midsection 306, and a threaded axial counterbore 339 which begins at rear end surface 324 of cylindrical rear section 320 and terminates at a shoulder 340 in the middle of midsection 306 (Figs. 9 and 12).

Outer drill 304 is shown in Figs. 9, 10 and 11. Outer drill 304 is similar to the outer drill 104 previously described. More particularly,

outer drill 304 comprises a substantially cylindrical rear section 342 which is formed integral with a generally cylindrical front section 344. Front section 344 has a larger outside diameter than cylindrical rear section 342, and an exterior shoulder 346 is formed at their intersection. Cylindrical rear section 342 generally terminates in an end surface 348. An axial bore 349 passes through front section 344 and cylindrical rear section 342. Outer drill 304 also includes three lips or dogs 351 at its rear end. Lips 351 are formed integral with cylindrical rear section 342 and extend inwardly of rear section 342. Lips or dogs 351 are disposed 120 degrees apart from one another, and are sized and shaped so as to define a trio of radial extending slots 353 therebetween. Lips 351 terminate in arcuate inner surfaces 355, side surfaces 358A and 358B, and parallel opposite end surfaces 357 and 359.

The generally cylindrical front section 344 of outer drill 304 is dissected by a plurality of intersecting inclined surfaces so as to define three flutes or blades 360. More particularly, the three flutes 360 comprise a trio of first inclined surfaces 362, a trio of second inclined surfaces 364, and a trio of third inclined surfaces 366. Flutes 360 are disposed 120 degrees apart from one another, and each terminates in a front end surface 368. Front end surfaces 368 are pitched at a 3 degree angle in the circumferential (i.e., non-radial) direction.

Inner drill 302 and outer drill 304 are assembled in a concentric manner so as to form the complete front drill head assembly 300. More particularly, inner drill 302 and outer drill 304 are positioned in the manner shown in Fig. 10, i.e., so that the inner drill's flutes 308 are aligned with the outer drill's flutes 360, and so that the inner drill's lugs 326 are aligned with the outer drill's radial slots 353. Then the two drill members are brought together so that the inner drill slips inside and makes a close sliding fit with the outer drill, with the inner drill's end surface 324 coming to rest against the inner end surfaces 357 of the outer drill's lips 351 (Fig. 9). The various parts of the inner and outer drills are sized and shaped so that when the inner drill's end surface 324 engages the outer drill's inner end surfaces 357, and the lugs 326 are located in slots 353 so that the outer drill's front end surfaces 368 are in alignment with but rearward of the inner drill's front end surfaces 316, the outer drill's inclined surfaces 362 will form a rearward extension of the inner drill's inclined surfaces 310, the outer drill's inclined surface 364 will form a rearward extension of the inner drill's inclined surfaces 312, and the outer drill's inclined surfaces 366 will form a rearward extension of the inner drill's inclined surfaces 314. In addition, the inner drill's lugs 326 are sized so that when the inner drill's end surface 324 engages the outer drill's inner

end surfaces 357, and the inner drill's flutes 308 are aligned with the outer drill's flutes 360, the lugs 326 will extend out through the outer drill's radial slots 353, with the first side wall surfaces 328 of the lugs extending parallel to and slightly spaced from side surfaces 356A of lips 351. The inner drill's lugs 326 are also sized so that they project out beyond the outer end surfaces 359 of the outer drill's lips 351 when the inner drill's end surface 324 engages the outer drill's inner end surfaces 357.

It is to be appreciated that the foregoing assembly can be achieved only if inner drill 302 and outer drill 304 are properly aligned with one another (i.e., so that the inner drill's lugs 326 are aligned with the outer drill's slots 353) prior to moving the two drill into engagement. More specifically, on account of the size and shape of lugs 326 and the size and shape of outer drill 304, if the lugs 326 are not properly aligned with the slots 353 when the two drill members are moved together, the end surfaces 330 of lugs 326 will encounter the inner end surfaces 357 of the outer drill's lips 351 and thereby prohibit the inner and outer drills from achieving the position shown in Fig. 9.

Rear support and drive assembly 400 is shown in Fig. 9. Assembly 400 comprises a hollow inner sleeve 401 having a threaded body section 403 and a substantially cylindrical collar section 405 at its front end. Collar section 405 has a larger outside diameter than body section 403, and an exterior shoulder 407 is formed at their intersection. Collar section 405 terminates in a front end surface 409, and body section 403 terminates in a rear end surface 411. A trio of key-receiving recesses 413 are formed in the sleeve's front end surface 409. Recesses 413 are similar in shape to the aforementioned openings 222 formed in the aforementioned rear support and drive assembly 200, and are spaced 120 degrees apart from one another. Recesses 413 have bottom surfaces 415. The axial bore in sleeve 401 is identified by numeral 419.

A coupling or connecting pin 421 is slidably disposed within sleeve 401. Connecting pin 421 has a cylindrical midsection 423, a cylindrical front section 425 having a reduced diameter relative to cylindrical midsection 423, and a rear flange 427 having an enlarged diameter relative to cylindrical midsection 423. A shoulder 429 is formed at the intersection of cylindrical front section 425 and cylindrical midsection 423. Cylindrical midsection 423 is threaded for a short distance rearward of shoulder 429. Connecting pin 421 is sized so that its cylindrical midsection 423 makes a close sliding fit in bore 419 of sleeve 401, in order that connecting pin 421 will be capable of independent movement relative to sleeve 401. Connecting pin 421 also includes an axial bore 431 extending forward from the rear

end surface 433 of rear flange 427.

Means are provided to urge connecting pin 421 forward so that the pin's rear flange 427 normally engages the rear end surface 411 of inner sleeve 401, in the manner shown in Fig. 9. More particularly, the rear support and drive unit 400 includes a drive adaptor 435 which fits over sleeve 401. Adaptor 435 has a rear section 436 having a stepped-down outer configuration adapted to be received by a Hudson chuck. Adaptor 435 includes an axial bore 437, an axial counterbore 439, and a shoulder 441 formed at the intersection of bore 437 and counterbore 439. Counterbore 439 is threaded for a distance rearward of shoulder 441 so as to permit the adaptor to be screwed onto sleeve 401, with the threaded sleeve's collar section 405 fitting in counterbore 439 and the sleeve's shoulder 407 engaging the adaptor's shoulder 441. A compression spring 443 is located in the connecting pin's bore 431 so as to urge the connecting pin forward away from the adaptor's interior end surface 445 and thus keep flange 427 of the connecting pin biased against the inner sleeve's rear end surface 411. This construction suffices to keep the connecting pin's rear flange 427 biased against the inner sleeve's end surface 411 without significantly impeding rotation of connecting pin 421 relative to sleeve 401. At the same time, pin 421 is capable of axial motion relative to sleeve 401 to the extent permitted by the gap normally extending between flange 427 and end surface 445.

As a consequence of the foregoing construction, it will be appreciated that rear support and drive unit 400 essentially forms a self-contained unit wherein connecting pin 421 projects its threaded front end outward from inner sleeve 401 and adaptor 435 and is yieldably biased into that position, and further wherein the connecting pin is capable of independent rotation relative to sleeve 401 and adaptor 435.

The front drill head assembly 300 is united with the rear support and the drive assembly 400 by screwing connecting pin 421 into the inner drill's bore 338 and threaded counterbore 339, until the connecting pin's shoulder 429 seats on the inner drill's shoulder 340. The various parts of the disposable cranial perforator are sized so that when spring 443 is holding the connecting pin's rear flange 427 against the rear end surface 411 of inner sleeve 401, the inner drill's lugs 326 will terminate short of the sleeve's front end surface 409. At the same time, however, the various parts of the cranial perforator are sized so that when the inner drill is forced back towards rear support and drive assembly 400, lugs 326 can extend into the lug-receiving recesses 413 formed in sleeve 401 and the rear end surface 359 of outer drill 304 can engage the front end surface 409 of sleeve 401, be-

fore the rear end surface 433 of the connecting pin contacts end surface 445. Adaptor 435 is sized so that when the front drill head assembly is united with the rear support and drive assembly, the front end of the adaptor will extend over the rear end of the front drill head assembly in the manner shown in Fig. 9.

The adaptor 435 is made to extend over the rear end of the front drill head assembly for a most important reason; specifically, this construction makes it impossible for an assembled perforator to be disassembled, with the result that reuse of the perforator is effectively prohibited so long as sterile conditions are a requisite. Disassembly is prevented inasmuch as the freely rotating connecting pin 421 must be held stationary in order for the front drill head assembly to be detached from the remainder of the perforator, and the connecting pin is rendered inaccessible on account of the fact that inner sleeve 401 is also inaccessible and therefore cannot be held still to allow for the unscrewing of adaptor 435 from sleeve 401.

To further inhibit reuse of the disposable cranial perforator, adaptor 435 may be formed of a low temperature thermoplastic so that the adaptor will destruct in a high-temperature autoclave during a sterilization procedure. Adaptor 435 also may carry a gas-sensitive label on its exterior surface to indicate whether the perforator has been subjected to a gas sterilization procedure.

Operation of the disposable cranial perforator is substantially the same as the operation of the reusable cranial perforator, and hence need not be redescribed.

Fig. 13 shows an alternative embodiment of the inner drill's lugs 126. In this case, a corner of each lug 126 is bevelled so as to provide a planar surface 129 which is interposed between and extends at an inclined angle (i.e., non-perpendicular) to both side surfaces 128 and end surface 130. Surfaces 129 serve as cam surfaces. They are engaged by the sleeve's surfaces 225B (Fig. 5) as the inner drill slips forward at the conclusion of drilling and such engagement assists forward movement of the inner drill relative to sleeve 202 and thereby promotes a more rapid disengagement of the inner drill's lugs 126 from sleeve 202.

Referring now to Fig. 14, there is illustrated the drilling implement in a preferred embodiment with its cutting end substantially through a skull. In the position illustrated, the common center point 118 has cut through the inner surface 115 of the skull 111. In addition, the cutting edges 118 of the shoulders 119 have also cut through the inner surface 116 of the skull 111 to define a wafer or pillow 121. This wafer or pillow has a disk like configuration with the center point 118 penetrating its axis, as illustrated, to hold it on the end of the drilling implement.

As partially illustrated in Fig. 14 the hole is formed by the drilling implement by first locating the drilling point with the center point 118. As the drill progresses inwardly, the inner drill member cuts a narrow diameter hole, followed by a wider diameter hole cut as the outer drill member passes into the skull. A shoulder 123 is thus formed between the inner and outer surfaces of the skull.

When the inner drill unit reaches the inner surface 115, as illustrated in Fig. 14, the spring means previously described is sufficient to force the inner drill unit forward, pushing the pillow 121 substantially free of the remaining portion of the skull to a position substantially as illustrated in dotted outline at 125. The pillow will ordinarily not be completely free of the skull. Because of slight non uniformities on the inner surface of the skull and because the cutting edges on the shoulders 119 are of limited length, a few very thin segments or bridges between the pillow and the main portion of the skull wall remain at the moment that the inner drill member springs inwardly. As a result, the pillow will ordinarily be hinged along a portion of its perimeter when it moves to the position shown in dotted outline at 125. In this position the pillow is positioned between the cutting edge of the inner drill unit and the dura 127, thus protecting the dura 127 from cuts and lacerations. When the inner and outer drilling elements are disengaged and stop rotating, the drilling implement is withdrawn. The surgeon may then manually remove the pillow with appropriate hand tools and proceed with the operation.

Advantages of the invention

Numerous advantages are obtained by using the present invention.

First, the present invention provides a cranial perforator having a reliable "safety construction" designed to permit forward penetration by the perforator only so long as the perforator's leading tip is encountering hard bone, and to halt forward penetration by the perforator as soon as the perforator's leading tip passes through the hard bone and before it encounters the soft tissue beneath the bone.

Second, the present invention provides a cranial perforator having an improved clutch means for coupling the front drill head assembly to the rear support and drive assembly, the clutch means being designed so as to assure automatic de-clutching even when the perforator is manipulated under non-axial loads.

Third, the present invention provides a cranial perforator which includes a uniquely formed centering point to assist in centering the perforator when starting a bore, so as to minimize the tendency of the perforator to skate across the skull.

Fourth, the flutes of the cranial perforator of this invention are well adapted to remove the skull material from the cranial opening in a form best suited for subsequent repacking in the opening when the opening is closed at the conclusion of surgery.

Fifth, the invention provides a cranial perforator which can be used with relatively low speed drills (i.e., drills operating at speeds of around 100 RPM), as well as with relatively high speed drills (i.e., drills operating at speeds of around 800-1000 RPM).

Sixth, the present invention provides a reusable cranial perforator better adapted to withstand repetitive non-axial loading, so that the perforator will not tend to fail after an indefinite period of use.

Seventh, the present invention provides a reusable cranial perforator which has a long operational lifetime, and which is easy to disassemble and to reassemble so as to facilitate cleaning.

Eighth, the present invention provides a reusable cranial perforator which disassembles into relatively few pieces, so as to facilitate disassembly and reassembly.

Ninth, the present invention provides a reusable cranial perforator which will be rendered totally inoperative if it is reassembled incorrectly.

Tenth, the present invention provides a disposable cranial perforator which cannot be disassembled without rendering the perforator totally inoperative.

Eleventh, the present invention provides a disposable cranial perforator which will indicate when it has been resterilized in an attempt to use it more than once.

Finally, the invention has the advantage that it is not likely to cause trauma to the brain or dura as the drilling implement cuts through the skull, and further creates a wafer of pillow which will remain between the dura and innermost cutting edges of the drilling unit.

The invention is susceptible to modifications other than those already described. Thus, the shapes of the cutting flutes may be changed. Still other possible modifications will be obvious to persons skilled in the art.

CLAIMS

1. A drilling implement for drilling holes in bone structures comprising, a drill head assembly including inner and outer coaxial drill members with the inner member having at least one drilling flute with a forward cutting edge, said cutting edge including a reentrant segment spaced from the outer end of said forward cutting edge and extending inwardly toward the axis of said drill members.

2. A drilling implement as claimed in claim 1 having a plurality of said flutes and with said cutting edges extending outwardly from a common center point, said common center point projecting forwardly of said forward cut-

ting edges.

3. A drilling implement as claimed in claim 2 including three flutes and with said common center point comprising a pyramid.

4. A drilling implement as claimed in claim 2 wherein the outer ends of said forward cutting edges form shoulders which project forwardly to a point short of the forward most position of said center point.

5. A drilling implement as claimed in claim 1 wherein said outer end of said forward cutting edge projects forwardly of said reentrant segment a distance in the order of magnitude of a least 100% and said reentrant segment extends inwardly a major fraction of the diameter of said inner drill.

6. A drilling implement as claimed in claim 5 including three of said flutes and a common center point from which said reentrant segments of said flutes radiate.

7. A method of drilling through bone structure comprising drilling a cylindrical hole through the bone structure with an annular channel being simultaneously cut with and at the bottom of the hole, whereby a cylindrical wafer or pillow is formed at the bottom of the hole when the bone structure is initially cut through along said annular channel, and discontinuing drilling immediately upon formation of said wafer or pillow.

8. A drilling implement substantially as herein described and shown in the accompanying drawings.

9. A method of drilling through bone substantially as herein described with reference to the accompanying drawings.

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